NASA/TP—2002–210776

Creating a Team Archive During Fast-Paced Anomaly Response Activities in Space Missions

Jane T. Malin
Johnson Space Center
Houston, Texas

LaDessa Hicks
Johnson Space Center
Houston, Texas

David Overland
Johnson Space Center
Houston, Texas

Carroll Thronesbery
S&K Electronics
Houston, Texas

Klaus Christoffersen
Ohio State University
Columbus, Ohio

Renee Chow
Ohio State University
Columbus, Ohio

February 2002

THE NASA STI PROGRAM OFFICE . . . IN PROFILE

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621-0134

- Telephone the NASA Access Help Desk at (301) 621-0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard
  Hanover, MD 21076-1320

NASA/TP—2002-210776

Creating a Team Archive During Fast-Paced Anomaly Response Activities in Space Missions

Jane T. Malin
LaDessa Hicks
David Overland
Carroll Thronesbery
Klaus Christoffersen
Renee Chow

National Aeronautics and
Space Administration

Johnson Space Center
Houston, Texas 77058-3696

February 2002

Available from:

NASA Center for AeroSpace Information
7121 Standard
Hanover, MD 21076-1320

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

This report is also available in electronic form at http://techreports.larc.nasa.gov/cgi-bin/NTRS

Creating a Team Archive during Fast-paced Anomaly Response Activities in Space Missions

Jane T. Malin, LaDessa Hicks, David Overland
NASA Johnson Space Center
Houston, TX 77058

Carroll Thronesbery
S&K Electronics
NASA Johnson Space Center
Houston, TX 77058

Klaus Christoffersen, Renee Chow
Cognitive Systems Engineering Laboratory
The Ohio State University
1971 Neil Ave., Columbus, OH 43210

ABSTRACT
This paper describes a Web-based system to support temporary Anomaly Response Teams formed from distributed subteams in Space Shuttle and International Space Station mission control, to handle anomalies during missons. The system was designed for easy and flexible creation of small collections of files and links associated with work on a particular anomaly. The system supports privacy and levels of formality for the subteams. First we describe the supported groups and an anomaly response scenario. Then we describe the support system prototype, Anomaly Response Tracking and Integration System (ARTIS). Finally, we describe our evaluation approach, and results of the evaluation.

Keywords
Digital library, organizational memory, community memory, World Wide Web, groupware.

INTRODUCTION
Within organizations, a number of types of computer-based library services can be provided to support task-oriented teams [4, 5, 7, 9, 10]. We were asked to design a system to support temporary Anomaly Response Teams formed from distributed subteams in mission control, to handle unexpected anomalies when they occur during Space Shuttle or International Space Station missions. Although the teams are temporary, the analyses and decisions produced by each team would be additions to an organizational memory, an anomaly response information archive. Our management sponsor wanted an archive of analyses done for and by anomaly response teams, so that relevant analyses from past work on anomalies could be found and applied to current cases.

Our design solution was a World-Wide-Web-based digital library and team memory. We used an iterative design approach, preceded by a study of Anomaly Response Team activities, based on observations, interviews and critical incident analysis of past cases [13]. In this work we encountered many of the issues that have been addressed in the work on organizational memories and digital libraries.

Because anomaly response teams work in fast-paced time-constrained situations, a main driver for the design was ease of use and minimization of work in creating and managing the collections of heterogeneous information that are used and produced by Anomaly Response Teams. As noted by Grudin [8], Rein et al. [10], Braa et al. [5] and Sorgaard [11], a supportive computer service requires work from its users. The cost of the work must not be too high for the benefit.

The system can fail because it is not worth enough to any one individual to reach a critical mass of usage [8]. In other words, the anomaly response information archive would be fragmentary if the support tool was not continuously useful and easily usable by team members during the mission. As Gronbaek et al. [7] note, users do not tend to see a cooperative work support system as anything other than support for their individual work. The system should feel like an individual workspace that also provides access to closely related work by other team members. The delimited and focused nature of Anomaly Response Teams helps keep collections small and relevant.

The emphasis on ease of use made it necessary to simplify or eliminate a number of functions of digital or Web-based libraries. Because of the heterogeneous information and processes used and produced by the subteams, a simple flexible approach was needed (cf. Grudin's exception handling challenge, 8). Users would not create documents or files in a standard format, and would rarely be collaborative authors. Indeed, the collection could provide a workspace for collecting both links and files in several formats. Thus, requirements for version control and locks, authoring standards and work flow process management could be minimized or eliminated [10]. Users would not be required to create structure in the collection, a difficult task [9]. Collection maintenance [3, 10] could be minimized because these collections are historical rather than generic, and would include contextual information provided by contributors of files or links [1, 9].

The nature of the distributed Anomaly Response subteams meant that the design would accommodate informality and privacy [1, 8]. Mechanisms for incremental entry and promotion of elements of the collections were used to support levels of formality and privacy. They also provided a simple form of collection maintenance as a by-product.

The problem of adoption [5, 8, 11] was addressed by our iterative design process and by integrating the support system with a new simple capability to capture interpreted mission data from control center workstation applications.

This paper describes the support system prototype, Anomaly Response Tracking and Integration System (ARTIS). First we describe the supported groups and an anomaly response scenario. Then we describe the support provided by the prototype. Finally, we describe our evaluation approach, and the results of the evaluation.

COOPERATIVE ITERATIVE DESIGN APPROACH

In our design work on intelligent systems software, we use an iterative method for analysis, design, prototyping and evaluation [12]. Since the majority of the method is generally applicable to innovative advanced software, we used this method in development of ARTIS. The method is oriented to incremental development and use of task descriptions and scenarios, prototypes, evaluations and requirements. Throughout this process, the understanding of the activities, environment and problems of the users is refined. Early work focuses on getting the goals and objectives right, to guide design and evaluation of a useful software product, but refinement of this understanding continues throughout the project [14]. This understanding is embodied in descriptions and scenarios, rather than formal models. Informal evaluations of prototypes by user representatives occur throughout. Finally, a formal evaluation is conducted when the prototype is mature enough to be likely to be judged useful and usable by the evaluators. After this evaluation, a brief requirements document is written that refers to the prototype and incorporates any changes that are recommended as a result of the evaluation.

Our project team included representatives of the two primary user groups, a former Mission Control Center (MCC) flight controller and a former Mission Evaluation Room (MER) engineer. The flight controller represented the management sponsor and the interests of flight controller users throughout the project. She provided the majority of the informal evaluations. The engineer was responsible for detailed design and implementation of the final prototype.

Our early analysis took the form of a study of anomaly response teams. This provided the initial focus on support for team coordination with a central repository of working information. Informal evaluations of early prototypes helped us learn that privacy and formality issues were important to the design, because the two primary user groups were accustomed to working separately until their positions were mature enough to present to the other group. As users saw the utility of the repository, they turned to consider ease of use, and made clear that is was a make-or-break issue in the fast-paced world of responding to space mission anomalies. Our concept matured to include a set of easy steps, varying in effort to correspond to the likely pace of activity during the anomaly response process. Late in design, the users sought integration and consistency with activities on console in the control center. The concept of simple window shapshots to capture interpreted mission data was the result.

ANOMALY RESPONSE TEAMS - THE SUPPORTED GROUPS AND THEIR DIFFICULTIES

This section begins with a summary of the design-relevant findings of the Watts et al. [13] study of Space Shuttle anomaly response activities. This study was based on observations, interviews and critical incident analysis [6] of past cases. The flight controllers and supporting engineers that make up the principal subteams in anomaly response begin their work independently, since each group is located in an independent ground support control room during the mission. When a problem is identified as an unexpected anomaly without a corresponding set of standard operating procedures, the system specialists from the two subteams begin working directly together. In coordinative meetings, each subteam brings information, analyses and recommendations on what should be done. Because the flight controllers on console in the control center cannot leave to attend meetings, a new team of flight controllers ("team 4") is assigned to handle the coordination and team meetings. The diverse roles, resources and information from each group are helpful to the process of anomaly response. Argumentation and advocacy concerning conflicting interpretations and positions help make the decision process thorough and broad. Additional team members outside of these two main groups come and go, to provide specialized information or to oversee the process from the perspective of the whole mission. People responding to the anomaly can be geographically and temporally dispersed.

The primary support strategy is to make it possible for people involved in the anomaly response process to share information with one another. There is need for an organized central repository of information and data, old or new, located or created. A large amount of information can be located, produced, tracked, distributed and used by various individuals for various purposes in the time-constrained anomaly response situation. Some transfer of documents and information is accomplished by walking around. Some paper-based and electronic archival activities occur during and after the mission. The information is not managed in a coordinated way across subteams. It may be hard to follow all the relevant activities because they are numerous and distributed. Members with urgent needs for new information may not know in a timely manner whether and where it is available, especially if they miss a meeting.

A digital means of collecting and managing information could provide significant benefits to anomaly response teams. The primary challenge is to provide that support in a way that makes it easy to use when the tempo of activity is high during the mission, and that produces an archive where it is easy to locate relevant information from past anomaly response activities.

A TASK SCENARIO AND ROLE OF ARTIS

This generic task scenario describes the situation from the point of view of flight controllers. A flight controller on a discipline console (specializing in a defined set of space systems) in the MCC front or back room observes a possibly anomalous event or trend in the real time data. The flight controller communicates this information via phone and voice loops to other flight controllers and the Flight Director as needed. (The Flight Director is the primary person in charge of mission control activities to support a flight.)

As time permits, the flight controllers manning the discipline consoles use various on-console tools such as plotters, data logs or playback to analyze data relevant to the anomaly. The flight controller begins work on a document to provide status information on the problem or anomaly. The flight control discipline gets an action from the Flight Director to develop a position on the anomaly.

The flight controller sends a "CHIT" request to the supporting engineers in the MER, a parallel engineering center, requesting assistance in analyzing aspects of the anomaly or its impacts. The engineers begin work on developing positions for a CHIT response.

An anomaly response team is formed, including "team4" flight controllers from the discipline, MER engineers and others from outside who can assist. Actions are assigned to gather all relevant information from the current mission and previous missions, and to perform analyses. Team members and others in the discipline on and off site develop the needed products. They work to isolate the problem, plan responses, run tests on the ground or in flight, develop new procedures, change flight rules, and so on, depending on the nature of the anomaly. Team 4 members report to the flight controllers on console in the MCC. Anomaly response team meetings coordinate the work during the mission until issues relating to the anomaly are resolved.

There can be several independent anomalies during a mission, and a parallel set of Anomaly Response Teams can be at work. Each team reports its progress daily to the Mission Management Team (MMT), and this is recorded in the MMT minutes.

Flight controllers will provide the ARTIS database with the initial description of an anomaly by capturing the display of mission data indicating that an anomaly exists. In addition, they will be consumers of ARTIS information by tracking what analyses have been done, what actions are recommended, and whether meetings are scheduled for investigating the anomalies.

Other "team 4" flight controllers support the mission but are not assigned to one of the three shifts which cover console operations during a 24 hour period. Until these flight controllers have been assigned a specific anomaly-related task, they will be simply consumers of ARTIS information, checking in periodically to maintain mission cognizance and to see what anomalies are being worked and what types of analyses are being performed. Upon receiving an anomaly response task, they will begin using ARTIS more actively, looking for information related to the anomaly and collaborating with others in performing and publishing analyses to support the anomaly response process. The team 4 flight controllers currently need to call in to the console, visit the console, and examine written console logs to keep abreast of mission events. With ARTIS, they will be able to reduce the number of visits to the console, thereby improving their own productivity as well as that of the flight controllers actively working on console.

MER engineers will have a similar role to the team 4 flight controllers, with respect to using ARTIS. Like the team 4 flight controllers, they will be primarily consumers of ARTIS information until they receive a specific request for an analysis. Remote off-site engineers who are called into the anomaly response process can also use ARTIS remotely because it is Web-based.

PROTOTYPE DESIGNS - SUPPORT FOR TASKS

The ARTIS prototype is implemented using a browser interface to a database. The prototype is operational, but only one Workspace is populated, with example data from one anomaly case.

ARTIS assists anomaly response team members in performing the following tasks:

- Find current anomaly information
- Find archived information related to the current anomaly
- Share anomaly information and analyses with other anomaly response team members
- Manage ARTIS collections

Finding current anomaly infomation is one of the primary motivations for anomaly response team members to use ARTIS. A team 4 flight controller can examine mission data describing an anomaly and search the ARTIS archives from the office. A MER engineer can check the list of action items and meeting notices to monitor other anomaly response activities.

Find Current Anomaly Information

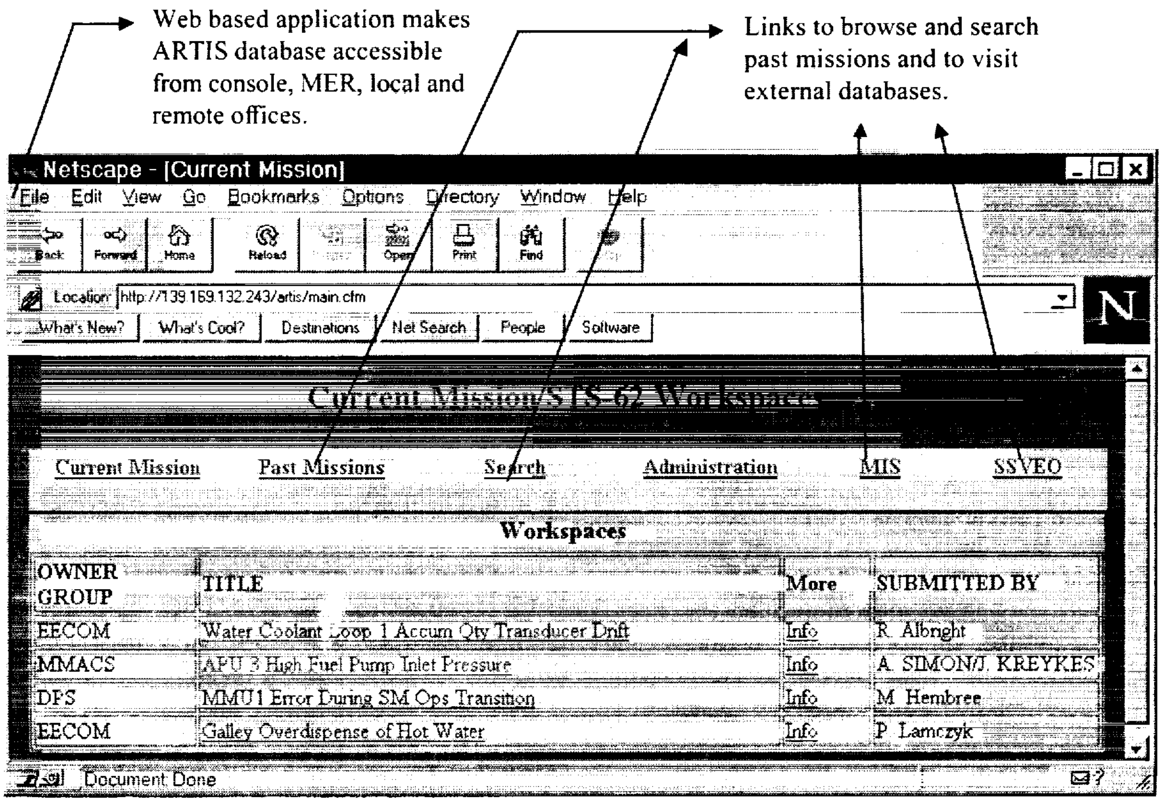

Figure 1. The Initial View Shows The Most Commonly Used Information And Links.

<u>What anomalies are being watched?</u>

The first display the user sees after logging into ARTIS is shown in Figure 1. Across the top of the display are links to "Current Mission", "Past Missions", "Search", "Administration", "MIS" (an external information source), and "SSVEO" (another external information source).

Because most of the interactions with ARTIS will involve the current mission, the current mission area is the default first screen after log-in. The "Workspaces" listed below indicate anomalies which are being worked for the current mission. Thus, upon logging into ARTIS the user immediately sees what anomalies are being worked for the current mission, key information for maintaining mission cognizance. Clicking on the "info" link will reveal a short description of the anomaly. Clicking on the name of the anomaly will access the Workspace (collection), and show all the documents, files, and links that have been entered.

The column identified as "Owner Group" refers to a specific flight control or engineering discipline, which also corresponds to group membership for the purposes of sharing private documents (described later).

<u>What Has Been Done To Investigate The Anomalies?</u>

The display in Figure 2 results from clicking on the name of a specific anomaly, "APU 3 High Fuel Pump Inlet Pressure", in this case. By showing the names of all the documents, files, and links entered under that anomaly, it answers the question, "What has been done to investigate the anomaly?"

Based on the log-in information, ARTIS identifies the group to which the individual belongs, thereby determining which "Private" files to show. The private files are visible to only group members so that drafts can be generated without exposing them to the entire anomaly response team. This allows collaborators to share ideas freely to generate analyses and reports without risking misunderstandings because they are still in draft form. By entering these draft documents in the Private area of ARTIS, collaborators need

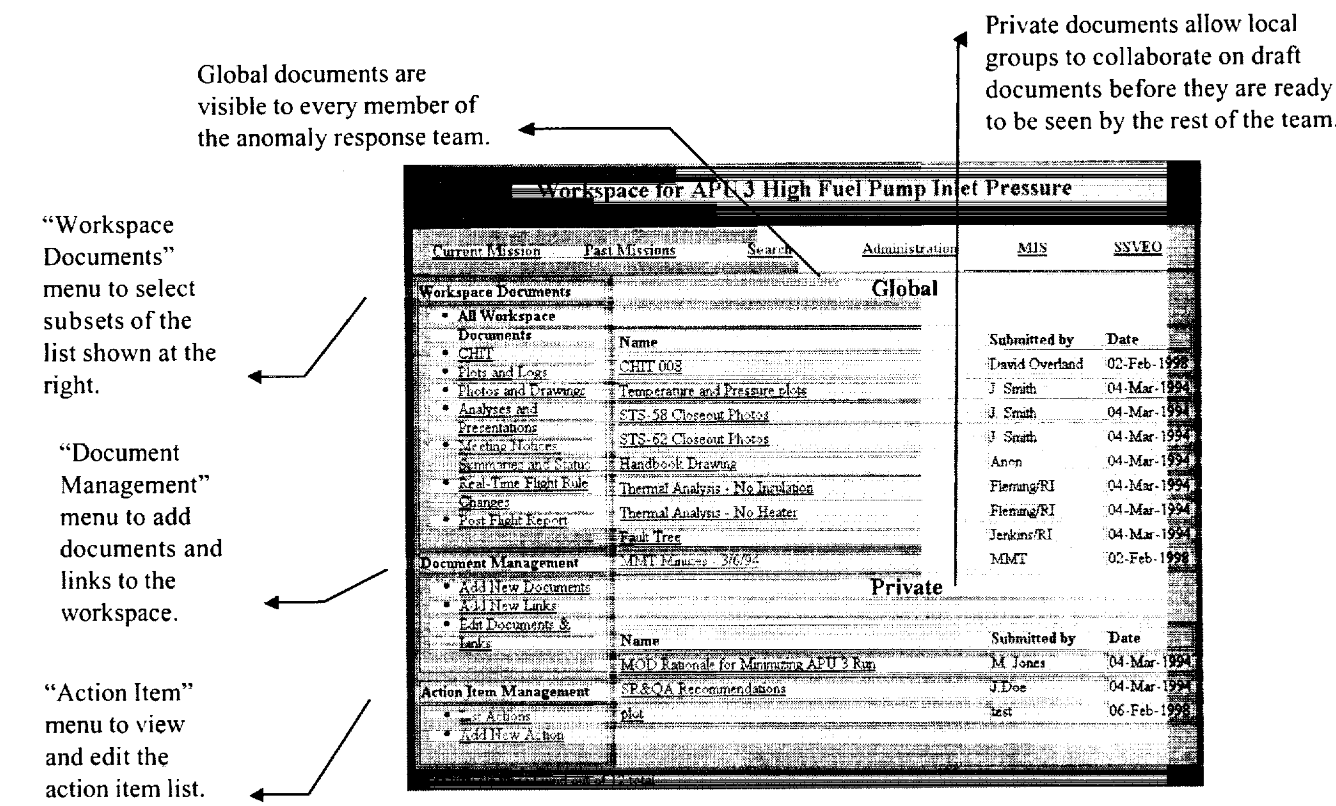

Figure 2. The Major Display Regions and Menus of ARTIS

not be physically co-located. For instance, a flight controller on console and two others in their offices could collaborate on a single report, using ARTIS to update the draft and to share notes and comments.

What were the outcomes (meeting notes, reports, action items) of previous meetings on this anomaly?

In Figure 2, the "Workspace Documents" selection called "All Workspace Documents" has been highlighted. This means that all categories of documents for this anomaly are being displayed at the right. To see a subset of the related documents, the user clicks on one of the categories in the Workspace Documents menu. For instance, clicking on "Meeting Notices, Summaries and Status" would cause only the line "MMT Minutes - 3/6/94" to be displayed at the right. This helps the user to eliminate clutter and isolate the objects related to specific information needs.

When is the next meeting to discuss an anomaly?

In this case, the user is interested to know if there is an upcoming meeting to attend. By clicking on "Meeting Notices, Summaries and Status" and seeing only one meeting report, she can quickly and confidently conclude that no meetings have been scheduled yet.

Find Related Archived Information

Finding related information was the specific assistance requested by the manager at the beginning of the ARTIS project. When an anomaly is encountered, access is needed to previous analysis reports that are relevant to the current anomaly. Some analyses consist of involved computer simulations; others involved physical experiments to test the operational characteristics of Shuttle hardware under very specific constraints. If a similar analysis has been performed in the past, much time can be saved in the anomaly response process. The user navigates to the related information by using the links that appear at the top of every ARTIS display (Past Missions, Search, MIS, and SSVEO).

By selecting the "Past Missions" link, the user can browse ARTIS databases for previous missions. By selecting the "Search" link, the user can search the archived ARTIS data for previous missions. The following search indices can be automatically associated with collections to support keyword search: vehicle ID, flight number, discipline (EECOM, MMACS, DPS, etc.), crew, and type of mission (e.g., spacelab, MIR docking, space station, type of payload).

ARTIS links to two other existing databases. The first is called Mission Information System (MIS), which provides a short synopsis of many anomalies and recommendations from previous missions. The second is called the Space Shuttle Vehicle Engineering Office (SSVEO) database, and it contains general Shuttle reference material plus information from the engineering office about the current mission.

Share Anomaly Information and Analyses with Other Anomaly Response Team Members

The initial request was for access to archived information, especially analysis reports, from previous missions. We faced a classic database problem, how to populate it with quality data. Our strategy was to serve current mission needs with the same actions that build an archive of the current mission. In the previous section, we showed how a web-based repository of information addressed the needs of finding current and past information. In this section, we show the strategy for making it easy to enter information about the current missions into ARTIS, without violating privacy concerns, and without requiring much effort to convert the current mission data into a searchable archive that can serve future missions.

Save mission data from the console

First, it is important for the flight controllers on console to be able to show the nature of the anomaly to the remainder of the anomaly response team. Figure 3 represents a hypothetical display of a portion of the console screen with mission data.

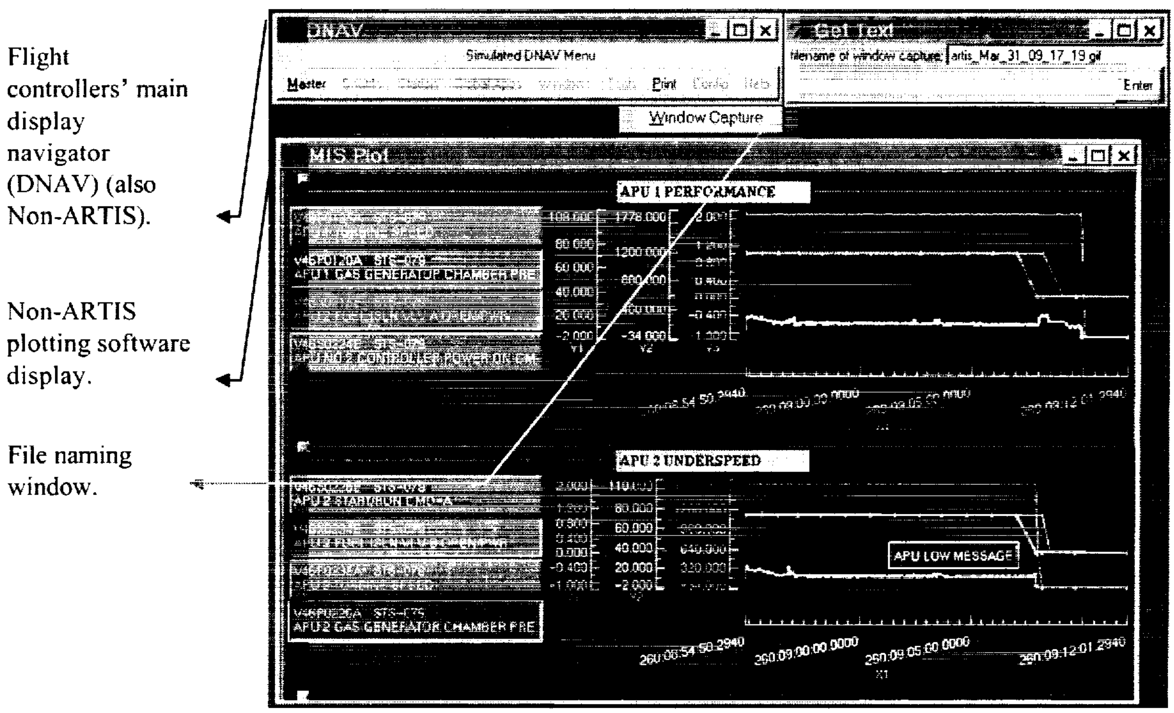

Figure 3. Window Snapshots of Mission Data can be Uploaded to ARTIS

The window titled MIS Plot contains an annotated data plot which the flight controller constructs using existing (non-ARTIS) software. To save this for ARTIS, the flight controller selects the Window Capture option from his/her main menu (the window marked DNAV). This selection causes the window to the right of the display to appear, showing a default filename (containing a date-time stamp for identification). If the controller is not rushed for time, she can rename the file to something more meaningful (e.g., APU_post_insertion.gif). Because the flight controller can be very pressed for time during this task, it was important to make the capture as quick as possible, hence the default filename, which the controller can OK without much thought. Once the filename has been entered, the cursor changes to a target and the controller clicks on the window to be captured.

Collection areas for these files are provided in the console environment, so that a large number of potentially useful window captures can be taken before actually deciding to enter selected files into ARTIS collections. Once an ARITS Workspace is created, relevant files can be uploaded into ARTIS for viewing by the remainder of the anomaly response team.

Upload files and links to the ARTIS database

Once a team member has produced a file containing an image or document to be shared with the remainder of the team, it can be uploaded to the ARTIS database. The display in Figure 4 resulted from clicking on the "Add New Documents" option under the "Document Management" menu at the left side of the display. In the interest of making the form as easy as possible to complete, default entries were already made, based on log-in and navigation information for all but the file name, descriptive name, and comments. All other entries are editable. For entries like "category" which have a limited set of options, those options were placed in a drop-down list to make them easily selectable. The document being entered in Figure 4 was entered as a "Private" document.

Some of the work of the team involves locating relevant information that is already available on the Web. A similar form is used to add links to other web pages by selecting the "Add New Links" option from the Document Management menu at the left. The user provides a descriptive title and may provide comments on the Web link. These forms provide some context and meta-data for each file and link. Even though externally linked information may change, the context information can still be useful.

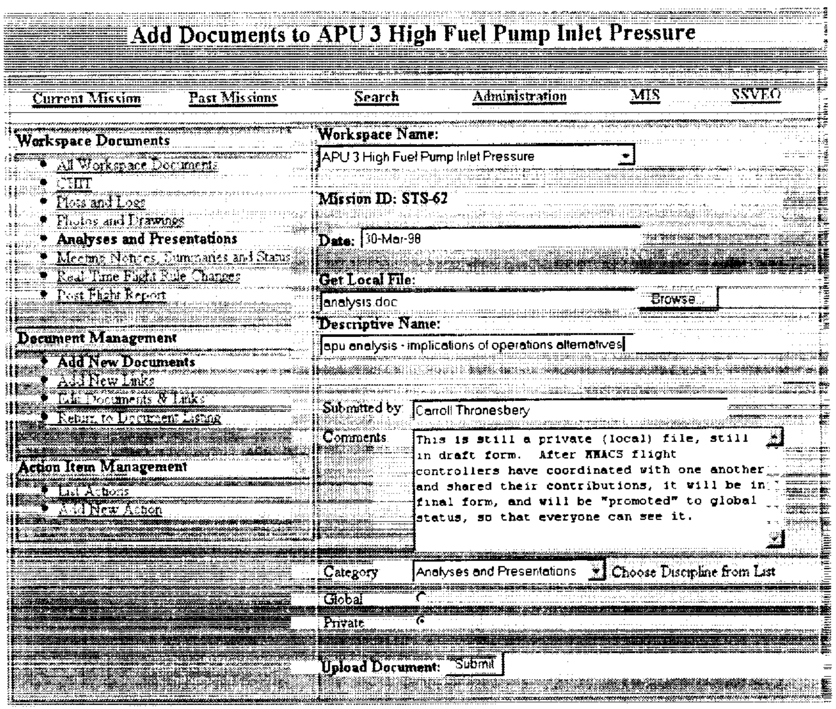

Figure 4. Files can be Uploaded to the ARTIS Database

Collaborate with group members

Collaboration with group members occasionally requires some privacy, while making the document available to people at multiple locations. Flight controllers on console and in offices may want to make drafts available to one another without showing them to the remainder of the anomaly response team. This is the purpose of a private workspace. When a person logs into ARTIS the association of that person with a private group is established automatically (e.g., user "tbery" has been associated with the MMACS flight controller group, so the only private documents he can see are MMACS flight controller private documents).

Promote analyses and documents to team-wide workspaces

Once a draft becomes final, it is time to move the document from the private workspace to the global workspace so the whole anomaly response team can see it. Figure 5 shows how a document currently restricted to private viewing by collaborators can be promoted to be globally accessible when ready. For instance, if the "MOD Rationale for Minimizing APU 3 Run" is now ready for viewing by the entire anomaly response team, the author can click on the "Move" button under the Promote column of the Private table below. Afterwards, any member of the anomaly response team can view it. The "Demote" option was provided in the Global area so documents can also be moved back to the Private area.

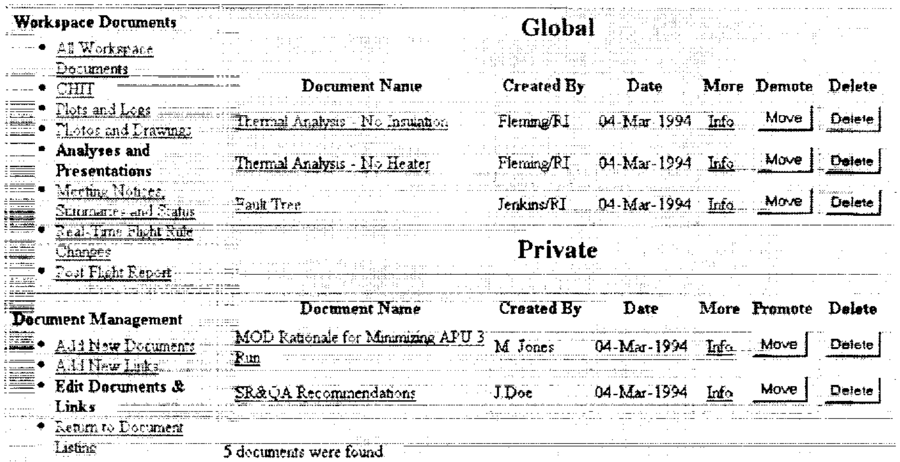

Figure 5. Private Documents can be Promoted for Global Access and Archiving when Ready.

Manage ARTIS Collections

Managing the ARTIS collections is a task that the anomaly response team does not currently have, so it is important that the management responsibilities are not burdensome. The nearest manual correlate they have is binding the analyses, reports, meeting notes, etc., into a 3-ring mission binder for future reference. Fortunately, there are not many new management tasks introduced by ARTIS. Adding users and assigning them to groups is a task that should not be performed often because the membership of each group tends to be stable. For instance, turnover in the MMACS flight controller group is not so high that maintaining a list of members of that group is burdensome. To add new users or groups, the administrator selects the appropriate menu option under the Administration menu (shown in Figure 6).

Figure 6 illustrates how a new workspace is created. This is a task that can be performed under some time pressure, so it needs to be streamlined. ARTIS fills in as much default data as possible, leaving the user to enter a workspace name and a workspace description. If the user needs to edit the default values, she simply selects that entry area and types over it.

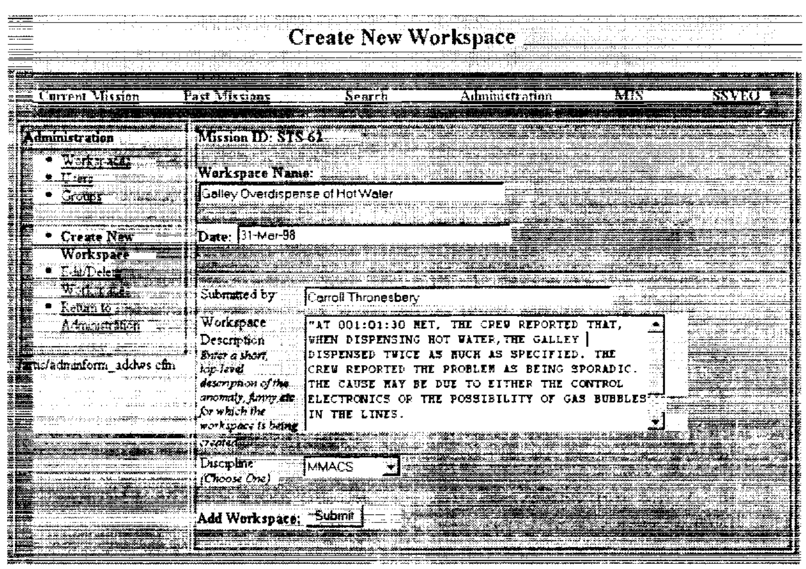

Figure 6. A Workspace for a New Anomaly can be Created with Minimal Effort.

At the end of a mission, global workspaces are kept as archives that can be referenced during future missions. The data collection areas and private areas of workspaces are purged.

EVALUATION METHOD AND RESULTS

Our approach to formal evaluation of prototypes is designed for advanced software for novel uses such as the multi-user applications for computer-supported cooperative work [12]. Because failures of such software are often due to misunderstanding of multi-user tasks and their difficulties, and problems of adoption [8], our evaluation focused on refining our understanding of the activity and getting some indicators of the utility or usefulness of the support strategy used in system [14].

At the usability level, the primary concern is with questions about implementation of the chosen aiding strategy (e.g., "should the database use queries or hypertext links?" "what should the structure of the menus be?"). While we were careful to develop a design with good usability, we chose to focus the evaluation on our understanding and the usefulness of the system. We noted that the strategies that we developed to achieve ease of use were above the level of traditional usability concerns. In our system, ease of use was a utility or usefulness issue.

Six current or former space shuttle flight controllers served as participants in the evaluation. The core of the evaluation consisted of demonstration-style walkthroughs of several anomaly response scenarios intended to showcase the main functions of ARTIS. The intent was thus to test the relevance of our design basis scenarios as well as to obtain feedback about how ARTIS addressed these scenarios. Participants were encouraged to "think aloud" as much as possible and to offer feedback on any and all aspects of the prototype. All of the sessions were audiotaped and subsequently transcribed.

Each session began with a "critical incident review" [6], in which participants were asked to recount the events of the last serious anomaly they had worked on ("serious" was defined as an anomaly where the team 4 group had been called in). They were asked to focus on the nature of how information had flowed among members of the anomaly response team and what, if any, difficulties were encountered.

Next, we solicited feedback from the participants on a schematic flow diagram depicting our conception of the major components of the anomaly response process. This diagram also included a list of what we thought of as the most important information resources supporting the anomaly response process as well as a list of the most significant bottlenecks in the process. Overall, the results of these exercises served to substantially reinforce our confidence in the model of anomaly response activities on which ARTIS is based.

The participants generally reacted positively to the idea of a centralized, remotely accessible repository of information about current and past anomaly response activities. There was unanimous agreement that ARTIS could represent a considerable improvement over some of the current methods of information capture and distribution during anomalies.

In the final portion of the evaluation, participants were given a chance to describe, in an open-ended fashion, how they thought ARTIS might or might not be useful. The following excerpt is representative of the majority of the responses: "It [ARTIS] certainly makes all the information from current flight, previous flights available in one common location and it allows the flexibility of anyone adding to this at any time. We don't have anything right now that does this. ... At least during the [STS-] 76 anomaly there was so much going on, but there was no common place to get the information. That's... what slows things down... and you can't really follow what's going on unless it's available... [it] takes a long time to figure out where all the pieces are coming from." Thus, in general, the evaluation served to substantiate and refine our understanding of the anomaly response process, as well as to reinforce our confidence in the usefulness of the assistance that ARTIS provides for anomaly response activities.

The evaluation uncovered concerns about how the database would be populated initially with information from past anomalies, and how it would be maintained. With clerical assistance, paper documents currently kept in 3-ring binders could be converted to ARTIS format to make them more accessible and digitally searchable.

There were also concerns that ARTIS might not be utilized if it forced a duplication of archival duties currently performed elsewhere. Thus, further work is needed on integration of ARTIS with currently used tools and work practices.

CONCLUSIONS

In this work, we found that a group support system can be designed for ease of use in a way that is distinct from usability. We found that to achieve an adoptable support system, we had to spend a significant amount of our effort on making a simple and flexible system. The work required to enter files and links and structure a collection has to be minimal. Although we considered providing a structured work process and tools to check consistency of hypotheses and evidence, we abandoned these concepts in favor of simplicity and flexibility.

ARTIS provides a hybrid between an organizational information repository and a World Wide Web digital library. It contains document and graphics files as well as links. Its contents could be authored by anyone, but members of the anomaly response teams control the collections. Context information is associated with each file and link. The maintenance of the collections as Workspaces has to be minimal and almost invisible to the users. Versioning is handled simply, with promotion to the Global area signifying permanence in the archives. Since the archives are historical, there is not a continuing need to maintain them for consistency with current organizational knowledge.

Currently, ARTIS is being re-implemented and extended to support new requirements of flight controllers for issue tracking.

ACKNOWLEDGMENTS

We thank the numerous flight controllers and MER engineers who have helped us with feedback and design ideas during this project. The NASA Office of Life and Microgravity Sciences and Applications supported this project work. We also thank Jurine Adolf for early prototyping and design work.

REFERENCES

1. Ackerman, M. S. Definitional and Contextual Issues in Organizational and Group Memories. *Information Technology & People*, 1996, 9(1): 10-24.

2. Ackerman, M. S. Augmenting the Organizational Memory: A Field study of Answer Garden. *Proc. Conf. on Computer-Supported Cooperative Work* (CSCW'94), 1994: 243-252.

3. Ackerman, M. S., and R. T. Fielding. Collection Maintenance in the Digital Library. *Proc. Digital Libraries '95*, Austin, TX, 1995: 39-48.

4. Ackerman, M. S., and E. Mandel. Memory in the Small: An application to Provide Task-Based Organizational memory for a scientific community. *Proc. 28th IEEE Hawaii Int'l Conf. of System Sciences* (HICSS), January, 1995, IV: 323-332.

5. Braa, K. and P. Sorgaard. Stages and Diversity in the Implementation of World Wide Web and Document Technology. *Proc 2nd IFIP 8.6 Int'l Working Conf. on Diffusion, Transfer and Implementation of Information Technology*. Ambleside, UK, 1997.

6. Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin*, 51(4), 327-358.

7. Gronbaek, J., M. Kyng, and P. Mogensen. CSCW Challenges: Cooperative design in engineering projects. *Communications of the ACM*, 1993, 36(4): 67-77.

8. Grudin, J. Groupware and Social Dynamics. *Communications of the ACM*, 1994, 37(1): 92-105.

9. Marshall, C. C. , F. M. Shipman III, and R. J McCall. Putting Digital Libraries to Work: Issues form Experience with Community Memories. *Proc. First Annual Conf. on the Theory and Practice of Digital Libraries*, 1994: 126-133.

10. Rein, G. L, D. L. McCue, and J. A. Slein. A Case for Document Management Functions on the WEB. *Communications of the ACM*, 1997, 40(9): 81-89.

11. Sorgaard, P. Work Behind the Service: Web Publishing and Changes in Document Production. *Proc. 1996 Information and Process Integration Conference*, Boston, MA. 1996: 387-396.

12. Thronesbery, C. and J. Malin. Field Guide for Designing Human Interaction with Intelligent Systems. In preparation (NASA TM reference for final version of paper in July).

13. Watts, J. C., D. D. Woods, and E. S. Patterson. Functionally Distributed Coordination during Anomaly Response in Space Shuttle Mission Control. *Proc. 1996 Symposium on Human Interaction with Complex Systems*, IEEE Computer Society Press: Dayton, OH, 1996: 68-75.

14. Woods, D. D., E. S. Patterson, J. M. Corban, and J. C. Watts. Bridging the Gap Between User-Centered Intentions and Actual Design Practice. *Proc. Human Factors and Ergonomics Society 40th Ann. Meeting*. Philadelphia, PA, 1996:

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 2002	NASA Technical Paper

4. TITLE AND SUBTITLE Creating a Team Archive During Fast-Paced Anomaly Response Activities in Space Missions	5. FUNDING NUMBERS
6. AUTHOR(S) Jane T. Malin,* LaDessa Hicks,* David Overland,* Carroll Thronesbery,** Renee Chow,*** and Klaus Christoffersen***	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Lyndon B. Johnson Space Center Houston, Texas 77058	8. PERFORMING ORGANIZATION REPORT NUMBERS S-886
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001	10. SPONSORING/MONITORING AGENCY REPORT NUMBER TP-2002-210776

11. SUPPLEMENTARY NOTES
*Lyndon B. Johnson Space Center, Houston, Texas; **S&E Electronics, Hosuton, Texas; ***Ohio State University, Columbus, Ohio

12a. DISTRIBUTION/AVAILABILITY STATEMENT Available from the NASA Center for AeroSpace Information (CASI) 7121 Standard Hanover, MD 21076-1320 Subject Category: 62	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This paper describes a Web-based system to support the temporary Anomaly Response Team formed from distributed subteams in Space Shuttle and International Space Station missions. The system was designed for easy and flexible creation of small collections of files and links associated with work on a particular anomaly. The system supports privacy and levels of formality for the subteams. First we describe the supported groups and an anomaly response scenario. Then we describe the support system prototype, the Anomaly Response Tracking and Integration System (ARTIS). Finally, we describe our evaluation approach and the results of the evaluation.

14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
space missions, anomalies, memory (computers), computer storage devices, integrated library systems, expert systems	16	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unlimited	Unlimited